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Final Report

"An Investigation of Coccolithophore Optical Properties Under Bloom Conditions: A Continuation"

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Purpose of Investigation

The major goals of my ongoing investigations have been to describe the bio-optical properties of coccolithophores and associated coccoliths in oceanic environments. Coccoliths are micron-sized calcium carbonate particles produced by coccolithophores (of the unicellular algal class, Haptophyceae) at abundances of 10^5 per ml. High concentrations of these particles are produced annually throughout much of the temperate oceans of the world; mesoscale patches of the coccolithophore, Emiliania huxleyi have been observed that drastically alter the marine optical properties.

My three goals of this particular project were to: 1) use satellite imagery to locate and study coccolithophore blooms, 2) use shipboard optical instrumentation to describe the attenuation, absorbance, and scattering properties in blooms of E. huxleyi, and 3) begin to compile sufficient biological data to predict the occurrence of these organisms in space and time in the world oceans.

Methods

We used a combination lab and field approach to study the coccolithophores in the Gulf of Maine. The laboratory studies used field isolates (from our work during FY88) and focussed on studying the optical properties of this organism at various growth stages. The field work served to describe the distribution of the organisms in space and time, as well as to perform in situ and shipboard optical measurements. Our in situ measurements allowed good spatial resolution of the optical features while the shipboard measurements allowed manipulation of the coccoliths to assess their overall importance to the optical signature. Basic hydrographic and biological measurements were also performed as part of the field program.

My studies were collaborative between Bigelow Laboratory and the University of Miami. With the help of the University

of Miami Remote Sensing Facility and Dr. S. Ackleson (Bigelow Laboratory), we used the Advanced Very High Resolution Radiometer to locate a coccolithophore bloom in the Gulf of Maine. We (myself, Dr. Ken Voss and A. Chapin of the Univ. of Miami, and Drs. P.M. Holligan, S. Ackleson, D. Townsend and Jeff Brown of Bigelow Lab and Dr. Charles Paull, Univ. North Carolina, Chapel Hill) then performed a 12 station survey within the bloom aboard the R/V Argo Maine, doing shipboard and in situ optical measurements (volume scatter, attenuation, absorption), biological measurements of pigments, cell/lith concentration, estimation of coccolith production rates, nutrient concentrations, and standard hydrological measurements. These results have been submitted to Limnology and Oceanography for publication (copy of manuscript enclosed).

Our results demonstrate that the tremendous modulation of the optical field in the coccolithophore "bloom" was caused by a relatively low biomass of plants (usually <1 mg chl/m3 at the surface). The shipboard backscatter measurements showed that 70% of the backscatter was due to coccoliths, with the remainder being due the associated cells. The large fraction of the scatter attributed to the cells (30%) was a surprise given their low biomass. These measurements allowed us to quantify the relationship between detached coccoliths and backscatter. Moreover, the shipboard measurements compared favorably with the in situ measurements of Dr. K. Voss. Upon returning from the cruise, our experiments with the EPICS flow cytometer at Bigelow Laboratory demonstrated that the optical properties of the coccolithophore, E. huxleyi, were a function of growth phase of the organism. We also were able to document the importance of intracellular, pre-extrusion coccoliths to the light scatter of the cells. This might explain the large fraction of light scatter attributed to de-plated coccolithophore cells in nature.

One major accomplishment of this work was the derivation of the relationship between coccolith concentration and back scatter in the blue and green wavelengths. This relationship, along with knowledge of the ratio between Bb(436nm):Bb(546nm) for the suspended coccoliths, allows us to use the improved bio-optical algorithm of Gordon et al. (1988) for calculating pigment concentrations, irradiance reflectance and other apparent optical properties within coccolithophore blooms. A second accomplishment of this work is the demonstration, using the flow cytometer, that the scattering properties of the organisms depend on their growth stage. Cells in log growth grew coccoliths but did not shed them. As soon as cells reached stationary phase, they dropped their coccoliths. This would suggest that by the time we observe the coccolithophore blooms by satellite, the cells are not actively growing. With more knowledge of growth-dependent variables, we expect to be able to better

estimate coccolith densities based on satellite reflectance data.

Follow-up Investigations

Following this work, my near-term objectives are to 1) perform further laboratory experimentation to understand the growth-dependent factors which affect coccolith detachment and formation, and 2) expand my studies into the western north Atlantic and Indian Ocean to understand the distributions of coccolithophores in space and time. For the past several years, we have been studying the coccolithophore blooms within the shelf waters of the Gulf of Maine. Satellite images have demonstrated, however, that blooms forming on the northeast flank of Georges Bank extend eastward into the adjoining continental slope waters. Blooms have also impacted the oceanic waters off the Scotian Shelf as well as the oceanic waters south of Iceland at 20 degrees west and 60 degrees north. I would like to document the frequency of coccolithophore blooms, the production rates of coccoliths, their inherent optical properties, and their subsequent fate in the oceanic realms of the North Atlantic and Northern Indian Ocean, using a combination of ship and satellite observations.

Statement "A" per telecon Dr. Richard Spinrad. Office of Naval Research/code 1123.

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